ON THE RELAXED STATE OF ACCOMMODATION

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It was 98 years ago that H. von Helmholtz, in his basic work which appeared in the first issue of *Graefes Archiv für Ophthalmologie* (Graefe's Archives of Ophthalmology), set down the concepts which, despite many attacks upon them, are still accepted today. In his well-founded opinion, all the processes leading to accommodation occur exclusively in the ciliary-body/zonular-fibers/lens system, which operates as a mechanically elastic unit. The lens of the eye, or its capsule, is an elastic body which will revert to nearly spherical form if free of outside influences. This is prevented, however, by the pull of the zonular fibers, which are firmly attached to the outer edge of the capsule and cause an oblation of the lens. The elastic pull of the zonular fibers is always present unless a contraction of the ciliary muscle changes this condition and thereby permits the lens to assume a more highly curved form. The ciliary muscle therefore acts as the only "living member" of the system; the other two members (zonular fiber and lens) are merely affected by the change in the physical relationships. Since in the doctrine of physiology contraction of a muscle is normally the result of active effort and the release of the muscle is the relaxed state, it is generally accepted on the basis of Helmholtz's precepts that the adjustment of the eye to distant points [far point] (extended ciliary muscle, relaxed zonular fibers, flat lens) must represent the relaxed state, while the accommodation of the eye to near points [near point] (contracted ciliary muscles, convex lens) must represent the active state of accommodation.

However, the conclusion from Helmholtz's observations just described is not very compelling. It does not show the actual relationships, as will

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be shown below. The actual relaxed state of accommodation must in all probability be somewhere between the far point and the near point (with the eye adjusted to a distance of about one meter). This realization is of extraordinary theoretical and practical significance. It is not to be ignored either in physiologico-optical studies or in the construction of optical instruments.

Anatomico-Neurological Indications of the Actual Relaxed State of Accommodation

Viewed anatomically, the ciliary muscle is a "smooth muscle." This type of muscle (e.g. intestinal muscle, blood-vessel walls), as opposed to the cross-striated skeletal musculature, is not induced to contract by the fibers of a given motor nerve. Its greater or lesser state of contraction is brought about by a change in the balance between the contracting (parasympathetic) and the relaxing (sympathetic) fibers of the autonomous nervous system. For this reason, for the smooth muscles there is no real state of rest, -- or, if there is one, it is at least not represented by the state of maximal contraction or expansion. For a long time it has been believed that the ciliary muscle was an exception in this respect, because only the contracting fibers of the parasympathetic oculomotor nerve were known, and it was believed that the ciliary muscle differed from all other smooth muscles in that it could be contracted at will.

In the past few years, however, this precept has been set aside in the field of innervation, particularly as a result of detailed histological studies by Meesmann. The ciliary muscle actually consists of a very highly developed system of fibers. The old division of the ciliary muscle into fibers running meridionally (Brücke's muscles), radially (Ivanov's muscles), and circularly (Müller's muscles) does not stand the test of precise criticism; the musculature is a much more tightly woven system, which can only be regarded as a unit. That orthosympathetic nerve fibers from the cervical sympathetic nerve extend to the ciliary muscle as well as the parasympathetic nerve fibers from the oculomotor nerve is of particular significance. Contrary to previous conceptions, then, the ciliary muscle, like all other smooth muscles, is controlled by both types of autonomous nerve fibers. Therefore no other behavior is to be expected of it than that observed in the other smooth muscles. Just as is the case with the other smooth muscles, it should have no definitely determinable relaxed state, or at least the state of full extension is not to be regarded as the relaxed state.

The only difference remaining between it and the other smooth muscles that is often encountered is thus the possibility of voluntarily influencing the state of contraction. But this very possibility has always been very problematical. The stimulus for accommodation is inseparable from the stimulus for convergence. Any convergence impulse deriving from an object in sight carries with it an accommodation impulse. The voluntary control of convergence, however, presents no problems from the viewpoint of physiology, since the movement of the eye is controlled by striated muscles of the same type as the skeletal musculature, and can therefore be affected by an act of will. To stimulate convergence it is sufficient to imagine a point within the field of vision and wish to fix on that point. At the same time, because of the unconscious connection between convergence and accommodation, accommodation also occurs.

Meesmann's anatomical findings are confirmed by several clinical observations. In the inactivation of the cervical sympathetic nerve (Horner's syndrome), besides the contraction of the pupil there are difficulties in adjustment of the eye for distance. The contrary case is to be found in hyperactivity of the orthosympathetic nerve (as in certain forms of Basedow's disease), where difficulties in near-point accommodation occur simultaneously with dilation of the pupil. It can thus be seen that the far-point accommodation as well as the near-point accommodation is stimulated by the autonomous nervous system, the former being brought about by a preponderance of the orthosympathetic and the latter by a preponderance of the parasympathetic element.

The observations of the pharmacological effects of certain nerve poisons also point in the same direction. Thus the parasympathetic stimulants or orthosympathetic depressants (such as pilocarpine and the ergot derivatives) normally lead to difficulties in far-point accommodation, while poisons that either suppress the parasympathetic nerves or stimulate the orthosympathetic ones (such as atropine or cocaine) have an adverse effect on the near-point accommodation. If the autonomous nervous system is largely cut off by certain drugs (as by an overdose of sulfonamides), it is not rare that the state of accommodation becomes fixed at a distance of about 0.5 meter. The eye then behaves like that of a full presbyopic who is at the same time afflicted with myopia to about 2 diopters.

Physiologico-Optical Studies of the Relaxed State of Accommodation

A. Adjustment of Optical Instruments

The observation is often made that in the adjustment of optical instruments, if free movement of the ocular is permitted myopic values are often favored. Especially young and inexperienced observers shift the oculars to values one or more diopters less than the refraction state measured for their unaided eyes. This condition also causes the difference in the position of the maximum in the statistical distribution of the state of refraction if the study is made first with the unaided eye and then by means of the position of adjustment of a telescope.

On observations with the unassisted eye the comprehensive works of Steiger[3] and Betsch[4] state that the frequency maximum of the refraction state is approximately +0.5 diopter. In the case of optical adjustment of telescopes, however, during the last war the author's observations of a large number of seamen agreed quite well with the relevant experiences of optical firms in that the maximum frequency lay not at + 0.5 diopters but rather at about - 1.0.[5] Thus between observations dealing with the unassisted eye and those dealing with the adjustments of optical instruments there is a gap of about 1.5 diopters. This differential can be explained without difficulty if we consider that the maximum frequency for vision profiles is normally determined by using an eye chart at a distance of from 6 to 7 meters, thus automatically requiring the eye to adjust for distance, while with telescopic observations changes in accomodation can largely be compensated for by moving the optics. Thus the observations with the unassisted eye pre-determine a certain state of accommodation from the beginning, while the adjustment of optical instruments permits the choice of the most suitable position of accommodation. If, however, this does not coincide with what is to be expected from the anatomical and clinical observations — the far point, or maximal extension of the ciliary muscle — that means that the far point does not represent the relaxed state of accommodation. The telescopic studies agree precisely with the clinical experience to the effect that the relaxed state of accommodation is to be found between the far point and the near point. The honor of being the first to recognize this condition and its significance must be accorded to Kühl.[6]

Diopters

Far Point
Near Point
Relaxed State of Accommodation

Age

Figure I. Dependence of the Position of Far and Near Points on Age according to Donders and the Probable Relaxed State of Accommodation from the Dioptrometer

In the past few years the accuracy of the assertions just made has been confirmed, particularly by Lau[7] and Mütze[8] with the dioptrometers they developed. In these instruments, virtual strip pictures whose position in the room can be changed by the movement of two paral-

lel grates. If clear-sighted observers are permitted to adjust the strip
picture for greatest clarity, we find that this does not occur at the
near point or far point, but rather at some position between the two.
(See Figure 1.) The younger the observer, the easier he can accommodate,
and therefore, the closer the point of highest clarity of the strip pic-
ture approaches. Lau writes of this: "On the basis of the first trials
it is expected that the eye accommodates to a given distance in studies
with this instrument. The adjusted value corresponds to an accommodation
of the eye where the forces of the ciliary muscle and the lens tension
equate. This equation is primarily dependant on the elasticity of the
lens, and therefore changes with increasing age."

b. Night Myopia

It is known that the human eye becomes myopic with decreasing il-
lumination, and that this is more marked the younger the person con-
cerned. Night myopia is caused in part by the error in resolution caused
by the dilation of the pupil and the change in the visual color, and in
part by the change in accomodation.[9] The effect of accomodation predom-
inates over all other influences in this phenomenon[10] and can be shown
in the behavior of the Purkinje-Samson mirror images in the eye.[11] Ac-
cording to the works of Otero, Duran, and Palacios[12] the accommodation
range decreases with decreasing adaptation light density. At adapta-
tion light densities less than 0.02 (full moon illumination) the young
eye no longer has any capacity for accomodation (Figure 2). For the clear-
sighted the accomodation is then set at -2 diopters. The idea of accep-
ting this position as the relaxed state of accommodation is appealing be-
cause due to the limited accuity of vision and the limited number of light
stimulii in the field of sight there should be no causes for active ac-
commodation. The value for the relaxed state of accommodation derived
from night myopia also agrees well with the value derived from the pre-
viously described studies.

Range of Accommodation

Near Point

Far Point

Density of Illumination in the Field of Vision

Figure 2. Range of Accommodation as a Function of the Light Den-
sity in the Field of Vision

c. Negative Accommodation

If the adjustment of the eye to the far point does not coincide with the relaxed state of accommodation, and is instead representative of an active process of accommodation, systematic studies must bring to light some evidence for the existence of negative accommodation of this type. This has, in fact, occurred. It has long been known that hyperopic persons show a specific *rest accommodation*. By using certain aids, such as the simultaneous use of parasympathetic depressant and orthosympathetic stimulant drugs, eg. atropine and cocaine, a far sharper "relaxation of accommodation" can be reached than can be attained by using only one such drug. It is also known that such persons often object to a full-correction lens of this type, saying that they can see better with weaker glasses. On the other hand, through systematic training of the sympathetic system, many near-sighted people can attain an improvement in their refraction correction without a corresponding correcting lens. Y. LeGrand[13] was able to show a short while ago that such training is also possible with the clear-sighted and far-sighted. If they are encouraged to look into the distance "with wide open pupils and wide open eyes" a far greater positive correction will be noted than they would otherwise be capable of. Morgan[14] found that the eye of a cat can be brought from its refraction position of -0.5 diopters to +4 diopters in the direction of far-sight through the stimulation of its orthosympathetic cervical ganglia. Cutting the parasympathetic fibers similarly causes a change in the refraction index from -0.5 to +3.5 diopters. If later the orthosympathetic cervical ganglia are also destroyed, the state of refraction then returns to the normal value of -0.5. According to Fincham[15], the negative accommodation can also be supported by corresponding simultaneous lessening of the convergence tension. The state of refraction of most humans is moved into the hyperopic values when they are encouraged to look through diverging prisms.

d. The Dependence of Clarity of Vision on Distance

Aubert and Förster[16] have already shown that for certain people the measurements of clarity of vision at different distances do not lead to the same results. In general, vision is sharper for near objects than for distant ones. Bouma[17] determined some years ago that the optimal distance for sharpness of vision is about 2 to 3 m. (See Figure 3.) At both shorter and greater distances to the object of vision, the sharpness is noticeably decreased.

Figure 3: Clarity of Vision as a Function of Distance from the Object [Bouma]

Relative Clarity of Vision

Distance in cm.

e. The significance of the Individual Portions of Objective Space for Sight

The normal methods of determining sight give a false picture of the actual significance of the individual portions of objective space in vision. Normally objects lying in the area from 0.5 to 2 meters from the eye are of greater importance than those nearer and further, since they must be noted and dealt with specifically in movement and in subconscious actions. The necessity of best vision in the distance is only present in certain tasks. From this it can be seen that even reletively near-sighted people (up to about -2 diopters) are not disturbed by their handicap in leading normal lives. They notice their nearsightedness mostly in the movies, when they must accommodate to the distant screen, or when they are engaged in certain occupations, as in sailing or driving an automobile, etc. Objects lying within 1 meter of the eye are solely important for occupational reason, or in reading writing, etc.

The observations of Helmholz on the form of the *true horopter*,[18] agree rather well with the significance described above for the individual portions of objective space in vision. He found that the true horopter consists of a steep cone whose base is formed of a Vieth-Müller circle contained by the horizontal plane of the eye of the observer and whose point lies on the ground at a distance of about one meter. He sees a very practical arrangement in this, since the evaluation of the relief, that is, the unevenness of the footing, is greatly simplified by this.

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modation lies precisely between the far-point and the near-point of the individual observer. This is significant for various reasons.

If the far-point of the eye is taken as the norm in visual acuity studies as is generally done, it should be noted that here we are already dealing with a certain degree of negative accommodation effort. There is always the possibility that, due to inauspicious circumstances, this effort is artificially increased and thereby the state of refraction may be falsely evaluated. Therefore, the old rule of refraction "the strongest positive and the weakest negative correction" is only relative and has no absolute significance. There is always the danger that due to a number of inauspicious circumstances — that is, those that encourage negative accommodation — the positive correction will be too strong. In optical instruments with freely adjustable optics, it should be noted that adjustment for the true relaxed state of accommodation is much easier here than with the unassisted eye methods, and therefore that limited negative adjustments from the zero adjustment or the positive adjustment are to be preferred.

Summary

The previous view that the far-point adjustment of the eye corresponds to the relaxed state of accommodation no longer agrees with the findings of anatomy, histology, and optometry. The ciliary muscle consists of smooth muscle fibers which are controlled by both parasympathetic and orthosympathetic nerves. The adjustment of accommodation can only be controlled voluntarily through the connection with the convergence stimuli. The differences between the ocular adjustments of optical instruments and the values of refraction measured for unassisted eyes, the studies using dioptrometers, the findings in night myopia, and the existence of a negative accommodation, the position of maximum visual acuity, and the form of the horopter all speak in favor of the hypothesis that the actual relaxed state of accommodation does not correspond with the adjustment of the eye to distance, but rather is to be sought in the middle between the far-point and the near-point.

Practical Significance of the Relaxed State of Accommodation

According to the anatomico-histological and physiologico-optical considerations just described, the relaxed state of accommodation does not coincide with the far-point adjustment. It is attained, rather, by the adjustment of the eye for objective points that lie between the near-point and the far-point, as can be seen from the table.

Probable Relaxed Position of Accommodation Derived from Various Methods

Method of Study	Probable Relaxed Position of Accommodation	
	in meters	in diopters
Histology of the Ciliary Body	None	None, at most the average between near-point and far-point
Difference between adjustment of optical instruments and refraction determination of the unassisted eye	Approx. 0.67	Approx. 1.5
Dioptrometer	Between near-point and far-point	Average of near-point and far-point
Night Myopia	Approx. 0.5	Approx. 2
Maximum Clarity of vision	Approx. 2	Approx. 0.5
Horopter	Approx. 1	Approx. 1

If we consider that the accommodation capacities of the individual observer show an extreme dependence on age, and also that the effect of geometrico-optical and of chromatic aberrations can reach 0.75 diopters, an impressive agreement can be seen from the various methods of study described. In fact, it appears that the actual relaxed position of accom-

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